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Slides

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SNOW SLIDES IN THE SELKIRK MOUNTAINS.

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It fell to the lot of the writer to spend the winter of 1885-6 at the summit of the Selkirk Mountains, for the purpose of observing snow slides, with a view to the proper protection of the Canadian Pacific Railway from their effects. The following paper embodies a few facts that may prove of general interest to the Engineering profession.

The Selkirk Mountains form a chain lying to the west of the Rocky Mountains. They are divided from them by the Columbia Valley, running approximately north and south, and through which the river of the same name flows. This river sweeps round the northern extremity of the Selkirk chain, forming what is called the "Big Bend," and then flows southerly into Oregon Territory, scooping out a deep valley, which divides the Selkirks from the Gold Range, lying further to the west. The Selkirks are thus bounded on either side, and enclosed at their northern end, by the Columbia Valley. Their length is about 250 miles in Canadian Territory, and width from 50 to 80 miles. The range is cut across by the route of the Canadian Pacific Railway some 70 miles south of the Big Bend.

In general character these mountains are lofty, rugged, and steep; intersected and diversified by narrow passes, and precipitous, rocky canons. The height of the highest peaks is ten or eleven thousand feet above the sea; long parallel ridges of not much inferior elevation may be frequently observed in close proximity, forming between them a narrow V shaped valley, whose sides extend upwards, at an even and very steep slope, for five or six thousand feet, and along the bottom of which there flows a turbulent mountain stream. The geological strata is the lower carboniferous, the rock being for the most part the clay and slate shales of that system, with interlaminated quartz veins. Such rock necessarily crumbles and degrades easily under the action of the weather, and large masses of debris are thus constantly gathering in the valley bottoms, while the mountain sides are deeply scarred by gullies and fissures.

The Canadian Pacific Railway ascends the eastern slope of the Selkirks from the Columbia Valley by the Valley of the Beaver and Bear Creeks, following the valley of the former first for about 14 miles, and the latter for 6 miles. The altitude ascended in this distance is 2,200 feet, and as the valley of the Bear Creek falls very rapidly in the last 4 miles of its descent from the summit, the railway, in order to make the ascent on practicable grades, has to leave the bottom of the Beaver Valley some 6 miles from its point of departure from the Columbia Valley, and climb up on the mountain side, following the contour of the slope. The effect of this is to throw the line high up above the valley-bottom—at some points as much as eight or nine hundred feet—and to give deep crossings of the ravines or gullies above spoken of, by which the mountain side is fissured. Some of these bridge crossings are 150 feet deep, while one—that of Stoney Creek—is 286 feet deep, making, probably, the highest wooden bridge on the American Continent. The descent of the Western slope is made by the valley of the Ille-cille-waite River, following what has been named "Roger's Pass" out of compliment to the Engineer who recommended the adoption of this route to the company. Here, as on the eastern slope, the descent of the valley is at first so rapid that it is impossible for the railway to follow the valley bottom. But the difficulty has been cleverly got over, and the

requisite fall obtained on a practicable grade, by running the line up a tributary valley and doubling back upon itself in the form of a loop. By this plan the line has been brought down to the bottom of the valley, at the cost of some three miles additional length, and the necessity for continuing it high up along the mountain side has been obviated.

The Selkirk chain forms, as it were, a lofty wall running north and south. Being very much higher than the mountains to the west, it is the first and chief barrier that the moisture laden currents of air from the Pacific Ocean encounter on their eastward passage. This warm air is intercepted and the moisture condensed by contact with the cold Selkirks, entailing heavy rain in summer and deep snow in winter; and it is interesting to note that the snow fall on the western slope of the Selkirks (being the place where the first contact with the warm air takes place) is much heavier than on the eastern slope; while the average fall on the Selkirk range much exceeds that on the Rocky Mountains. The greater the difference in temperature, the larger will be the condensation taking place, and consequently the heavier the fall of rain or snow. Thus in cold winters the snow may be expected to be deeper than in mild. This conclusion is verified by observation. The winter of 1884-5 was extremely cold, the thermometer during the latter part of December marking, for some days, many degrees below zero, and reaching, on the 24th of that month, a minimum of -42° , and this was succeeded by a January of great cold during the first half. The snow fall during that winter at the Selkirk Summit was very large, aggregating more than 30 feet in depth, while during ten consecutive days there was a fall of no less than nine feet. The winter of 1885-6 was much milder, and the total snow fall 15 ft. 9 ins. The mean temperature for the month of December was $+21\frac{3}{4}^{\circ}$, and the lowest -1° ; the snow fall during the same period was only 3 ft. $4\frac{1}{2}$ ins. In January the mean temperature was $+2^{\circ}$, and the minimum -30° , while the snow fall was 7 ft. 2 ins. The greatest snow fall in any 24 hours occurred between a.m. of the 23rd and a.m. of the 24th, when $17\frac{1}{2}$ inches fell with a mean temperature of -8° . From a.m. of the 23rd to a.m. of the 27th, $40\frac{1}{2}$ inches fell, while the mean temperature was $^{\circ}$, and this was much the heaviest snow fall experienced in any four consecutive days. The lowest temperature occurred on the night of the 21st, when -30° was recorded; and it is significant that the period of lowest temperature immediately preceded that of greatest snow fall. February was a mild month; the mean temperature was $+27^{\circ}$, the minimum -2° (on the last day of the month), and the snow fall 2 ft. $3\frac{1}{2}$ ins.

But though a high temperature causes a diminution of the snow fall, it is always accompanied by more wind than prevails with a low thermometer. Though there were no instruments for measuring wind velocity and pressures, still personal observation testified that during the mild winter of 1885-6 there were more frequent and more violent gales than during the cold winter of 1884-5. Often, too, while it was quite calm in the valleys, the gale could be heard roaring in the mountain tops. The effect of these frequent gales is to brush the snow off the exposed and prominent parts, and to heap it into the pockets and basins of the mountain side. These form the gathering places for the avalanches, or snow slides, which occur at intervals throughout the winter; and it can easily be understood how the masses of snow, thus packed in by the wind, increase until they lose their balance, as it were, and toppling over, or sliding out, rush down the mountain side, with accelerating velocity. As a matter of direct observation, slides are most frequent and largest during or immediately after very violent wind, when the thermometer is standing high. But from the preceding argument it seems probable that the wind, as the indirect agent, has more to do with the slide than the rise in the thermometer. There is never violent wind with a very low thermometer, and slides seldom occur at such temperature. Thus, though the snow fall is the prime cause of the slide, and the deeper the snow the greater the slide as a rule, yet we see that in a mild winter, with moderate fall, the more frequent and violent winds, as compared with a cold winter, tend to compensate for the reduced snow fall, by drifting the "pockets" to overflowing, and thus to maintain the avalanches at something like a constant quantity. The slides of the winter of 1885-6 were certainly less in bulk than those of 1884-5, but there was no such difference as would be inferred from a direct comparison of the respective snow-falls; and in some places slides occurred in the former year where there were none the year before. But though it is true that year by year the slides may be looked for to much the same amount, there are

unmistakable evidences, in the extent and length of old slide tracks, partially covered with timber of some years' growth, that there are occasional winters when exceptional conditions prevail, and when the slides descend in stupendous volume.

There are two classes of slides; what may be called the "bench slide" and the "gully slide." The gully slide issues from a narrow and deep cleft in the mountain side, which extends upwards for perhaps one or two thousand feet. At the top of this cleft there is probably a deep pocket or basin in which the snow gathers. At the mouth, which is some 800 to 1,500 feet above the valley, the great heap of debris—the accumulation of many years—commences. It spreads out fan-like, and its width at the valley bottom may often measure over 1,200 feet. Winter after winter, and many times during the same winter, the slide rushes down the gully and shoots out upon the debris heap—the *talus* as it is called—loosening and displacing masses of rock in its course. These gully slides do not bring down large quantities of snow on each occasion; ten or twelve thousand cubic yards is about a maximum. The first slide probably follows the centre line down the *talus*, leaving in its course small heaps of hard packed snow. The second encountering these obstructions, deflects to the right or left, following the line of least resistance; the third behaves in like manner; and so on, so that by spring the whole of the "fan" has been passed over, and the snow heaped up along its base.

The slope of these debris heaps varies from $1\frac{1}{2}$ to 1 to 3 or 4 to 1, according as room is afforded in the valley for them to spread. The velocity of the slide depends upon the angle of the slope, the height from which it comes, and the condition of the snow. During early winter when the snow is light and powdery, and lying in this condition to a considerable depth, the slide is impeded by gathering snow as it descends, and the velocity is not very great, probably not exceeding 30 miles an hour. But later, when the slide-track has been worn smooth by frequent avalanches, the slide sometimes descends with terrific velocity. Observation and the careful weighing of various considerations induce one to rate this velocity as high as 100 to 120 miles per hour. A measure is obtained from the velocity of the wind generated by the slide. It will readily be granted that a mass of some ten or twenty thousand cubic yards, descending rapidly, will of necessity cause a strong current of air, while at the same time the velocity of the current will not be greater than that of the mass generating it. On either side of one of these fast snow slide tracks, at the bottom of the slide, may sometimes be seen the evidences of great wind force. Healthy trees, from a foot to two feet in diameter, are broken, leaving shattered stems 15 to 20 feet in height, split and torn as if struck by lightning. Sometimes the wind continues beyond the slide, tearing for itself a track through the standing timber, and leaving a sharply defined lane in its rear.

The velocity of wind required to do such work must be very great. The writer has personally noticed the action on standing timber, of a gale having a recorded velocity of 68 miles per hour (in Scotland, February, 1884), and though large numbers of trees were blown down, yet the effects were much milder, and the velocity plainly less than those of a snow slide wind. The effects produced by the latter are more comparable to those of the most violent tornado, the velocity of which has been recorded as over 100 miles per hour. Again, the velocity acquired by a body falling 2,000 feet freely in space would be 240 miles per hour. If we assume that on a steep slide track, having a similar vertical height, one half of this velocity were acquired—and with a good crust on the snow and other conditions existing favourable to velocity, this is not an unwarrantable assumption—it would amount to 120 miles per hour. In experiments made with a toboggan having on it a man weighing 180 lbs., on a snow slide track with a slope of 1 in. 36 (angle $15^{\circ} 30'$), it was found that the velocity acquired in a run of 318 feet was 43.36 miles per hour. The vertical height corresponding to this slope and distance is 85 feet, and the velocity that would be acquired by a body falling freely through 85 feet vertical is 506 miles per hour. Doubtless the velocity acquired by a toboggan is greater than that acquired by a snow slide on a similar slope, but still this experiment goes to shew that the velocity of a slide may be even considerably greater than that assumed. The writer had only one opportunity of personally noting the time of descent of a fast slide. This was one which occurred on the 5th of February. The time of descent, after issuing from the mouth of the gully, about 800 feet above the

valley, was somewhat less than 20 seconds; the rate of final velocity would, therefore, be something over 50 miles per hour, without allowing for the initial velocity the slide may have had on leaving the gully. The slide track was not steep, and there were no wind effects produced in standing timber at the foot of the slide.

It is only from considerations such as the foregoing that any estimate of the velocity of slides has been arrived at. It is seldom that one happens to be sufficiently near to a slide at the time of its occurrence, or in a sufficiently safe position, to observe its time. But though there is evidence to show that very high velocities are sometimes attained, yet it seems probable that such is not frequently the case.

The other form of avalanche occurs when the snow gathers upon a wide 'bench,' situated perhaps two or three thousand feet above the valley. When the accumulated snow becomes too great to hold its position longer, it slips over the edge, and rushes down the mountain side, on a track from a thousand to fifteen hundred feet in width. The quantity of snow brought down in this manner is very much greater than that by the gully slides, and though the velocity is usually less the effects are more overwhelming. In one such slide, covering a track 1100 feet wide, the quantity brought down roughly measured 250,000 cubic yards, and in former years the quantity has been far in excess of that. These bench slides do not come frequently during the same winter, as do the gully slides. It seems as though the whole winter's accumulation were carried off in one effort, and not brought away piece meal as in the other case.

The weight of hard packed snow composing a slide varies from 25 to 38 lbs. per cubic foot, according to the state of the atmosphere and the amount of pressure to which it has been subjected in coming down. In spring, when wet snow rolls down in large balls, the weight is greater than in midwinter; but some slides that had come down in midwinter, when the snow was perfectly dry, weighed 34 and 35 lbs. per cubic foot. The greater the velocity of a slide, the heavier the snow composing it becomes, owing to its being more compacted than when the slide travels slower.

The time of year when slides are largest and most frequent is from the middle of January to the latter part of February. These are "winter slides," formed of large masses of quite dry snow. In March and April there are numerous "sun slides," caused by the melting of the snow and ice, but these are not of any importance as compared with the others.

In erecting structures for the protection of the line of Railway, the governing principle is that they should offer no resistance to the slide. The force generated by the rapid descent of masses so large and heavy, is such that no structure that could be built would withstand it. Where the line runs along, and is "benched" into the mountain side, in the manner that has been described, the sled is constructed so as to continue the slope of the mountain, and shoot the slide across the track into the valley below; and the more nearly the slope of the shed roof coincides with that of the mountain side, the less will be the shock it receives from the passage of the snow. Where the line runs along the valley bottom, and slides descend from either side, strong cribs are built parallel to the track, with roofing between, while the backs are filled in with earth at a gentle slope, that allows the slide to rise up and pass over the line. By carefully observing the action of slides, and erecting sheds at all places where required, the line can be so protected as to run trains in safety, and with regularity, throughout the winter, no matter how great the avalanches may be. Though the Company has not succeeded in doing this thoroughly during the past winter, yet this failure has arisen rather from the impossibility of erecting all the requisite sheds during the short preceding season, than from inability to cope with these great forces of nature.